(2) The problem is not so simple as Gale thought it to be. Aside from hue, tint or chroma, or both, may also be effective to determine attention; and the importance of the variable factors depends partly upon objective conditions, and partly upon the predisposition of the observer. The judgments are not difficult; and now that we have some idea of the factors involved, a repetition of the experiment with stricter control of stimuli should yield a satisfactory answer to our general question.

XXVI. A Preliminary Study of Vowel Qualities

By J. D. Modell and G. J. Rich

The experiments reported in this paper were undertaken as a test of Köhler's earlier work with only approximately pure tones. Köhler employed tuning forks as stimuli; and his observers reported that the series of tones ranging from 163 to 4,000 v. d. gave a series of vowel qualities which could be arranged like those of color. Just as in the case of color there is a series of qualities from red through several nuances of orange to yellow, and from yellow a second series to green, and so on, so there runs a series in the phenomenal tone-system from *u* (moon) through *u-o*, *o-u* to *o*, and from *o* through *o-a*, *a-o* to *a* (father), and so on through *e* (prey) to *i* (machine).[1] In later experiments, in which he used Stern variators with interference apparatus, Kohler determined more accurately the pitch of the pure vowels; added those of *s*, *f*, and *ch* to the upper, and of *m* to the lower region of the scale; and concluded that the pure vowels fall regularly in octaves.[2] Since, however, we wished to know whether observers untrained in continental vowels would give the same judgments, and since Köhler himself holds that vowel qualities are to be found in all relatively simple tones, we have restricted our investigation to the preliminary aspects of the problem.

Apparatus.—We used as stimuli four Stern variators which gave a total range of 100-1200 v. d., a piston-whistle of 1072-3400 v. d., and an Edelmann-Galton whistle from 3560 to 5770 v. d. The variators were tuned by beats with König forks, and the two whistles by the Kundt dust-method. In our first experiments the whistles were blown by pressure on a rubber bulb; but since the pressure could not be rigorously controlled, we later actuated all instruments by air from a tank-gasometer. Weights were added, to give sufficient pressure for the high variator and the whistles. A record was kept of the amount of pressure both at the tank and at the mouth of the instrument, since it was found necessary to adjust the amount of pressure for the particular instrument if we were to obtain the best quality of tone. The pressure varied from 1.8cm. of water for the 300-600 variator to 14.0cm. for the Galton and 15.0cm. for the piston-whistle. All instruments were so connected with the tank that they could be instantly actuated at full pressure. There were two sources of error in the apparatus; a constant error of not more than 1%

[1] W. Köhler, Akustische Untersuchungen, II, *Zeit. f. Psych.*, lviii, 1911, 59 ff.

[2] See also *Zeit. f. Psych.*, lxiv, 1913, 92 ff.

when the temperature was 22-23 C., due to imperfections in the variators; and a temperature error, which never exceeded 1.2%, due to changes in the temperature of the room in which the experiments were conducted. In spite of our attempts to perfect the apparatus, the series of tones was not uniform in quality; there was a decided difference in quality between the lowest variator and the next above, between the highest variator and the piston-whistle, and again between the piston and the Galton. Furthermore, the lower and higher tones of the 300-600 variator were weaker than the tones in the middle of its scale. We could not be certain, therefore, that the observer did not associate certain judgments with certain points in the scale.

Method.—A series of 48 stimuli was prepared, in which the tones advanced regularly by intervals of thirds and fourths from 100 to 268, by whole tones from 268 to 536, by semitones from 536 to 3570, and by whole tones from 3570 to 5770 v. d. Ten series, five ascending and five descending, were given alternately to every observer. To avoid habituation, one tone out of its regular order, but within the same range of pitch, was inserted after every four or five stimuli. The judgments on these extra tones became part of the record, but were omitted from the final results. The observers were Dr. E. G. Boring (B), instructor in the department; Mr. F. S. Kleinman (K), student in psychology; Mr. W. F. Edgerton (E), a student untrained in psychological observation; Mr. G. J. Rich (R), graduate student in psychology, and Dr. H. P. Weld (W), assistant professor of psychology. W alone had had training in music and phonetics. Two sets of instructions were employed. The first three observers above mentioned sat in an adjoining room which communicated with the sound-room by a speaking-tube, and were instructed to write down the vowel-sound which they heard. This method was discarded, because from lack of training in phonetics the observers wrote the vowels in many different characters; so that in the end we were forced to have the reports interpreted, in conformity with continental pronounciation, before the judgments could be understood. This difficulty was obviated by the second method. The observer now sat in the room with the apparatus, though in such a position that he could not see it, and was instructed to reproduce the vowel which he heard or (where strict reproduction was vocally impossible) to pronounce the judgment. All observers were given extended practice before the experimental work began. They were told to regard the tone as singing or speaking a vowel to them. We began with *u* and *i*, as Köhler suggests; then added the remaining vowels; and later took many short series of tones at various parts of the scale. We found it necessary also to point out to the observers the American peculiarities of the vowels *a* and *e*, the former being rarely pure, and the latter having a decidedly diphthongal character. The procedure in the experiments proper was as follows. The experimenter gave the ready-signal, and in about two seconds produced the first tone of the series; the duration of the tone was roughly one second; it was repeated two or three times, or oftener if the observer desired; the judgment was recorded, and the apparatus was set for the next observation. The single experiment did not exceed two minutes, and in the later stages of the work a complete series was run off in thirty-five or forty minutes.

Results.—We found that, under the instructions of the experiment, all observers were able to hear vowel qualities in tones; and, with

one exception, all gave results similar to those of Köhler. Aside from *a*, observer E reported no pure vowels; the mixed forms, *u-o*, *o-a*, *a-o*, etc., were reported, however; and it seems probable that habituation carried E beyond the pure vowel to a point at which the new quality appeared. We have attempted to find the pure-vowel values by averaging the pitch-numbers for which he gave a judgment either of the vowel itself (*a*), or of a combination in which the vowel predominated, every such number being weighted according to the number of judgments. For the other observers, the results are the frequencies of the different judgments for every tone of the series. For our present purpose we need consider only the cases in which the judgment was that of a pure vowel. To obtain an average value for every vowel, the frequencies of the tones judged as a given vowel have been averaged, and each one weighted by the number of relevant judgments. The mean variation has then been calculated for each one of these averages, the single values being weighted in the same way. We have also averaged the values of every vowel for all observers, and finally have averaged the M. V. For the sake of comparison, we have worked out by the same method Köhler's results for his first series with himself as observer. All these results are shown in the following table:

	Vowel				
Observer	*u*	*o*	*a*	*e*	*i*
B	229 ± 49	576 ± 46	1057 ± 209	1778 ± 191	3455 ± 293
K	340 ± 48	630 ± 72	1378 ± 194	1875 ± 75	3941 ± 372
E	(273)	(904)	(2425)	(3569)	(4360)
W	267 ± 36	588 ± 62	1233 ± 177	1967 ± 150	4141 ± 355
R	287 ± 36	606 ± 48	1103 ± 122	1997 ± 110	3439 ± 460
Köhler	223 ± 56	468 ± 85	1139 ± 95	2265 ± 233	3480 ± 409
Average of B, K, W, & R	281 ± 33	600 ± 18	1193 ± 113	1904 ± 79	3744 ± 297
Average of M. V. for B, K, W, & R	42	57	175	131	370

No M. V. was computed for observer E, because it would be in no way comparable with those of the other observers. The averages themselves are only very roughly comparable.

If we look at the individual results, we find that the four observers stand in almost the same order as regards the relative position of the different vowels in the scale. K is usually the highest; then come R, W and B. There are only three inversions of this order, one for *a*, and two for *i*. *Some observers, then, tend to place the whole series of pure vowels higher than others.* When we compare the average of the four with Köhler's results, we find that it is somewhat higher for *u*, *o*, *a*, and *i*, and lower for *e*. The M. V. also shows large differences. Considered relatively to one another, the separate values indicate the size of the region over which the pure vowel is heard; but this is, of course, much smaller than the actual size of that region, because the values near the average have the greatest weight.

If we consider the averages of the four observers, *an octave-relation can be made out between u, o, and a, and between e and i, but hardly between a and e.* It is surprising that the M. V. of *e* is smaller than that of *a;* we had expected that *e,* owing to its naturally diphthongal character, would be the more troublesome.

Results of this sort can do nothing toward settling the current controversy regarding the nature of the vowel-sounds. We thought however that, if Köhler's theory is correct, then the fact of vocality ought to appear fairly plainly in tones such as those which we employed, and ought to appear for observers of various type and training. It does appear; and even if the turning-points are in some measure determined by the inequalities of our tonal series, still they are reported as turning-points of vowel-change; the pitch-numbers may have been somewhat shifted, but the vocality remains. Whether Köhler is right or wrong, it is noteworthy that vocality can at all, with this degree of consistency, be heard into or heard out of the tones employed.